Monitoring the environment with a Cloud Robotics Service

Ludovico O. Russo

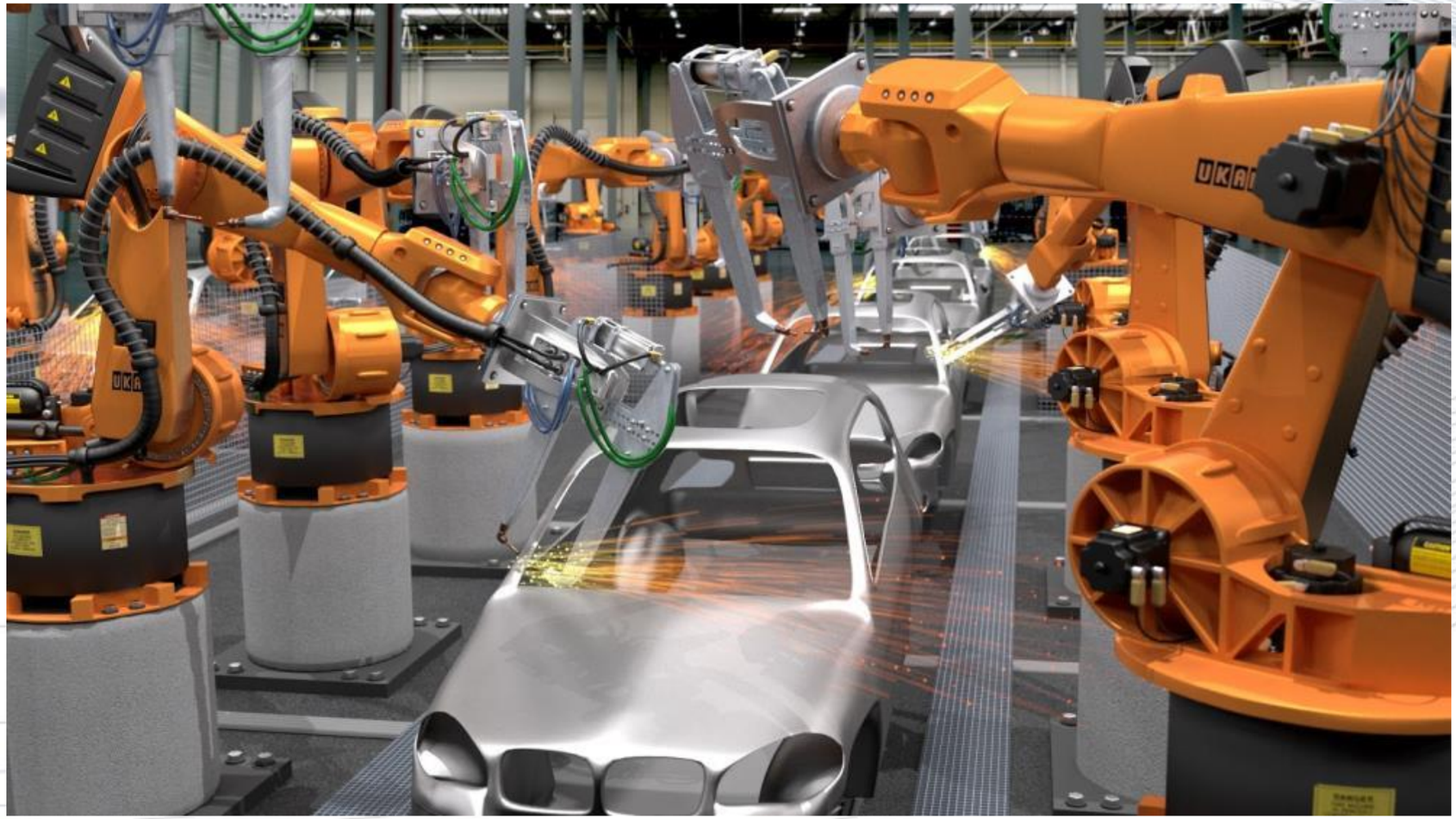
ludus.russo@gmail.com

Bicsi

Outline

- Introduction
  - Service Robotics
  - Autonomous Navigation
- Cloud Robotics
- Robot Based Environmental Monitoring
- Conclusions

Industrial Robotics



Service Robotics

A service robot is a robotic system design to assists human beings

Bicsi

Professional VS Personal

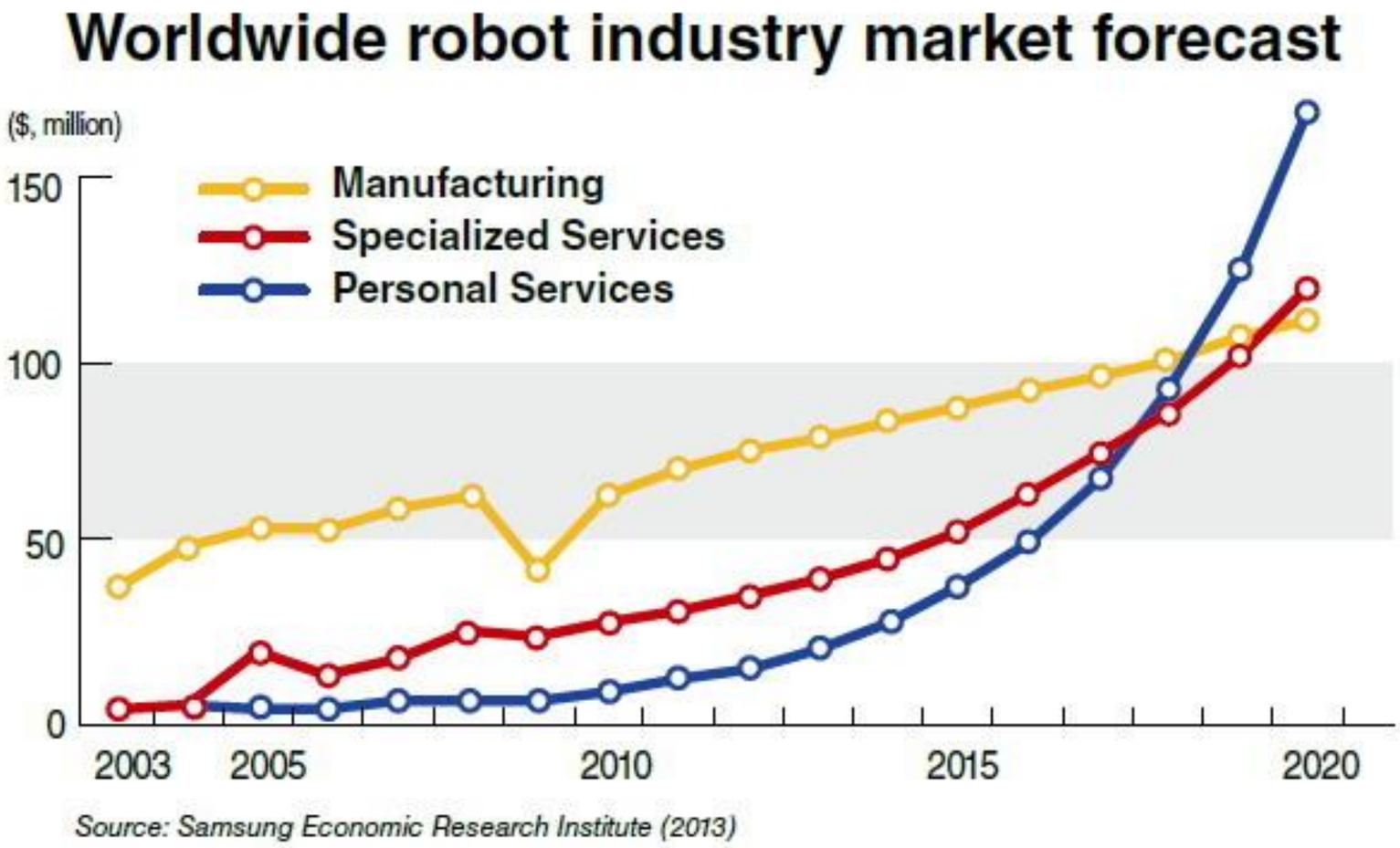
Professional Service Robots help people in their workplace:

- Agriculture
- Logistics
- Security & Monitoring

Personal Service Robots assist people to perform domestic tasks:

- Vacuum Cleaners
- Toys & Education
- Disable people assistant

Service Robotics Market is Growing fast



All forecasts agree with:

- Industrial Robotics market is near to saturation
- Service robotics market is growing exponential

Technological Constraints

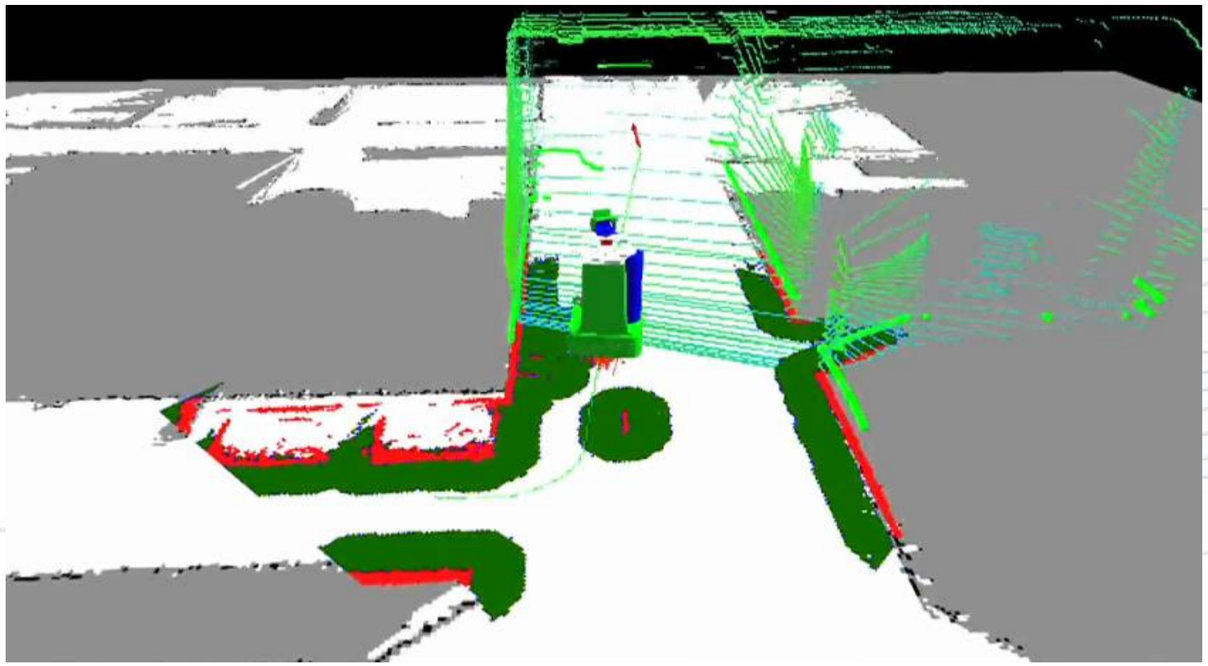
A Service Robot usually runs under **unstructured environment**

- **high intelligence** needed to solve tasks that are very simple for humans
  - Manage high quantity of data from the environment
  - Develop high level models
  - Make decision fast
- Battery Capacity
- Size and weight of the Robot (drones)
- Costs

Bicsi

Autonomous Navigation

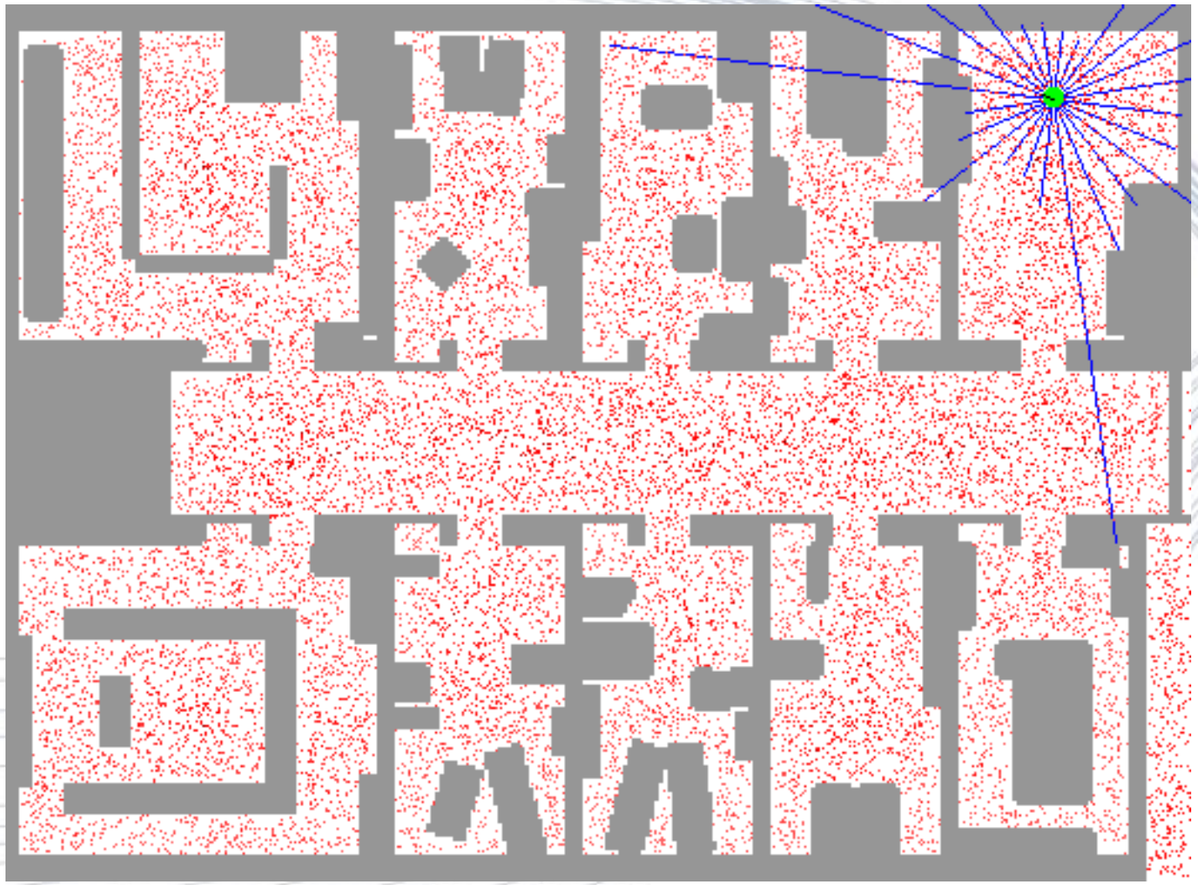
Set of capabilities a mobile robot **must have** to accomplish 4 foundamental tasks



- Self-localization inside a know environment
- Map building of the environment
- Path planning
- Path following

Bicsi

Localization and Mapping



Localization (pose tracking)

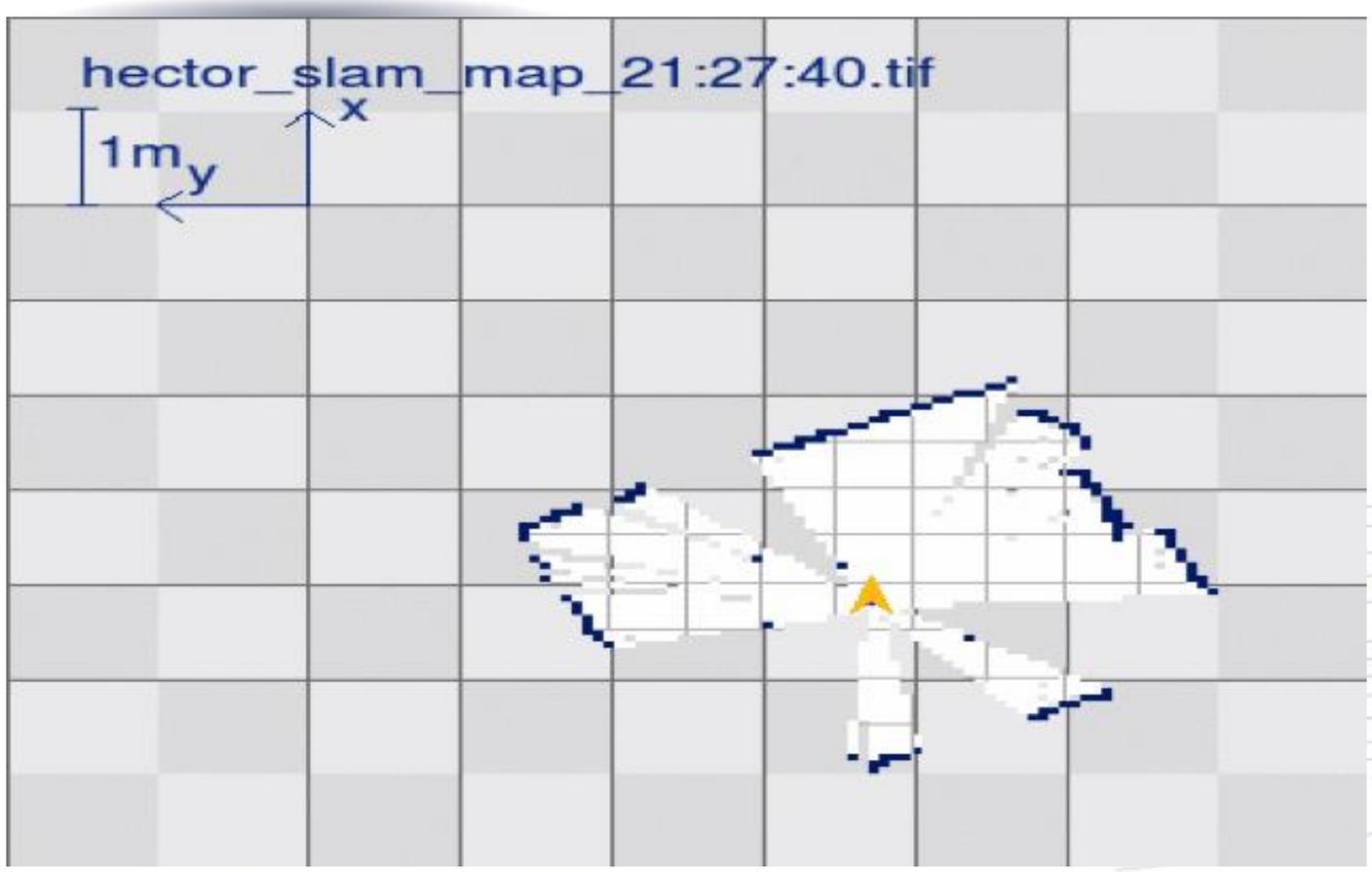
- I know the model (map) of the environment and I want to localize in it

Mapping

- I know my position in the environment and I want to build a model of the environment

Bicsi

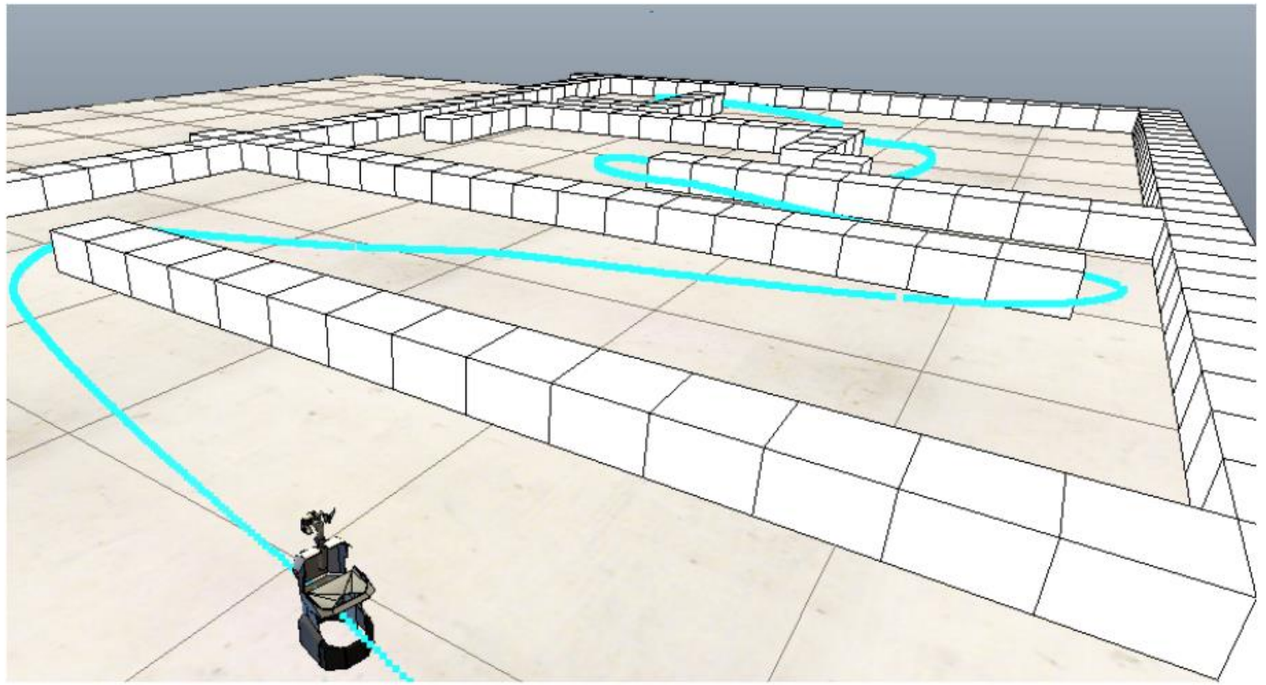
Simultaneous Localization and Mapping (SLAM)



SLAM

- Often Localization and Mapping must be executed at the same time.

Path Planning and Following



Path Planning (gmaps)

- I know the robot position and a target position (goal) in the map and I want to compute a path to reach that goal

Path Following (a car driver)

- I know the robot position, the goal and the path. I want to reach the goal by following the path in a safe way.

Bicsi

Probabilistic Robotics

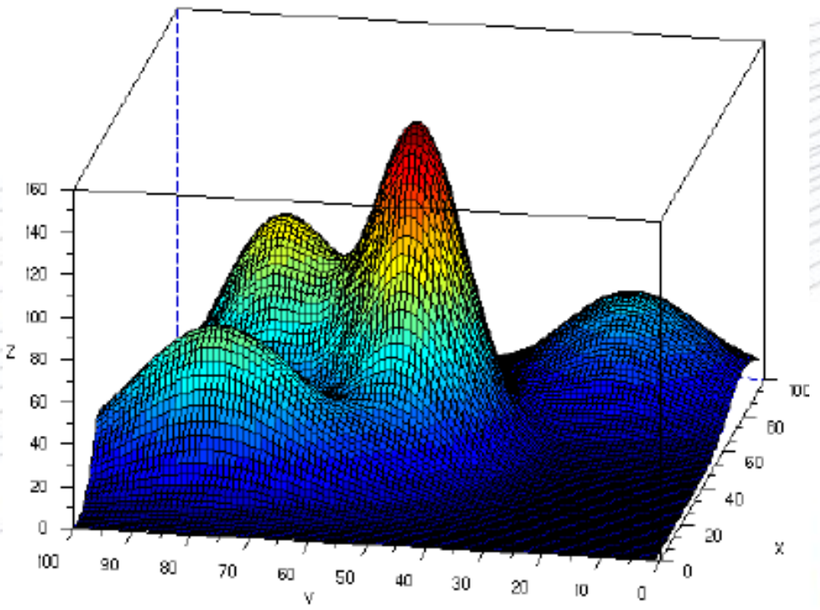
- Environment, Sensors, Robots, Models and compotentions introduce **Uncertatinty**
- **Probabilistics Robotics** properly models uncertainty in algorithms

PROs

- Robustness
- Better scaling in complex environment

CONs

- High Computational Resource



Bicsi

Cloud Robotics

- Onboard Intelligence is a Limitation in Service Robotics
- Can we delegate part of this intelligence remotelly?

The Cloud Robotics Paradigm

- **Leveraging internet based technologies to enhance robotics application**
- Introduced by J. Kuffner in 2010
- IoT, Industry 4.0, ….

Issues

- Complexity
- Real Time

Benefits

- Cloud Computing
- Big Data
- Collective Robot Learning
- Human Computation (telepresence)
- Open Source and Open Access

Bicsi

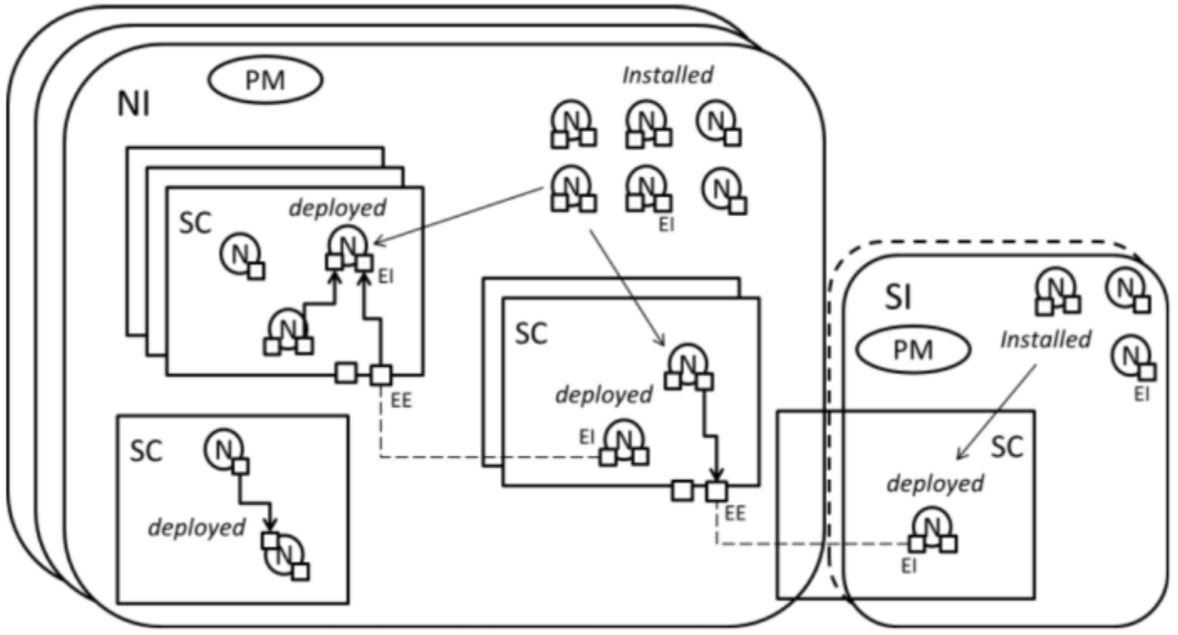
ROS: the Robot Operating System

- Framework for Robot Application Development
- Collection of Libraries, Tools and Conventions
- Ecosystem and Community

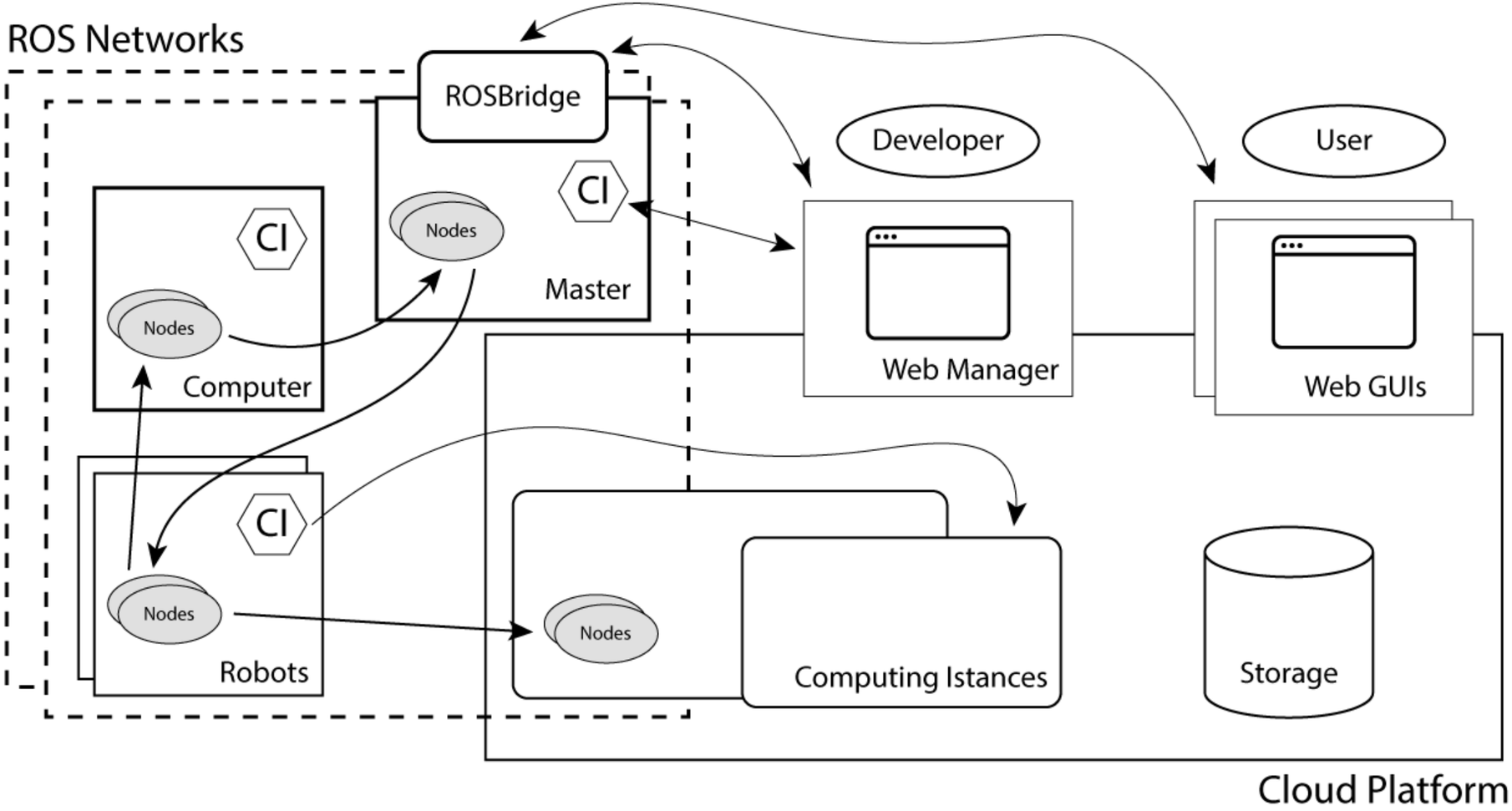
Bicsi

HBR Cloud Robotics Platform

- Platform as a Service (PaaS) to develop Robot Application
- Simple Restful API to manage the Platform



HBR Cloud Robotics Platform



Robot Based Environmental Monitoring

Sensor Networks

- Sensor Networks are a common application of IoT
  - Distributed Network of Sensors managed by a cloud application
- Application
  - Monitoring
  - Diagnostic

Virtual Sensor Networks (VSNs)

- A Cloud Robotics Alternative to Sensor Networks:
  - Mobile Robot
  - Autonomous Navigation
  - Environmental Sensors Onboard
  - Centralized Management
- PROS:
  - Simple to manage and configure
  - No Intervention on the environment
  - Reconfigurable
  - Scalable
- CONS:
  - No RT Measurements

Bicsi

Why Virtual?

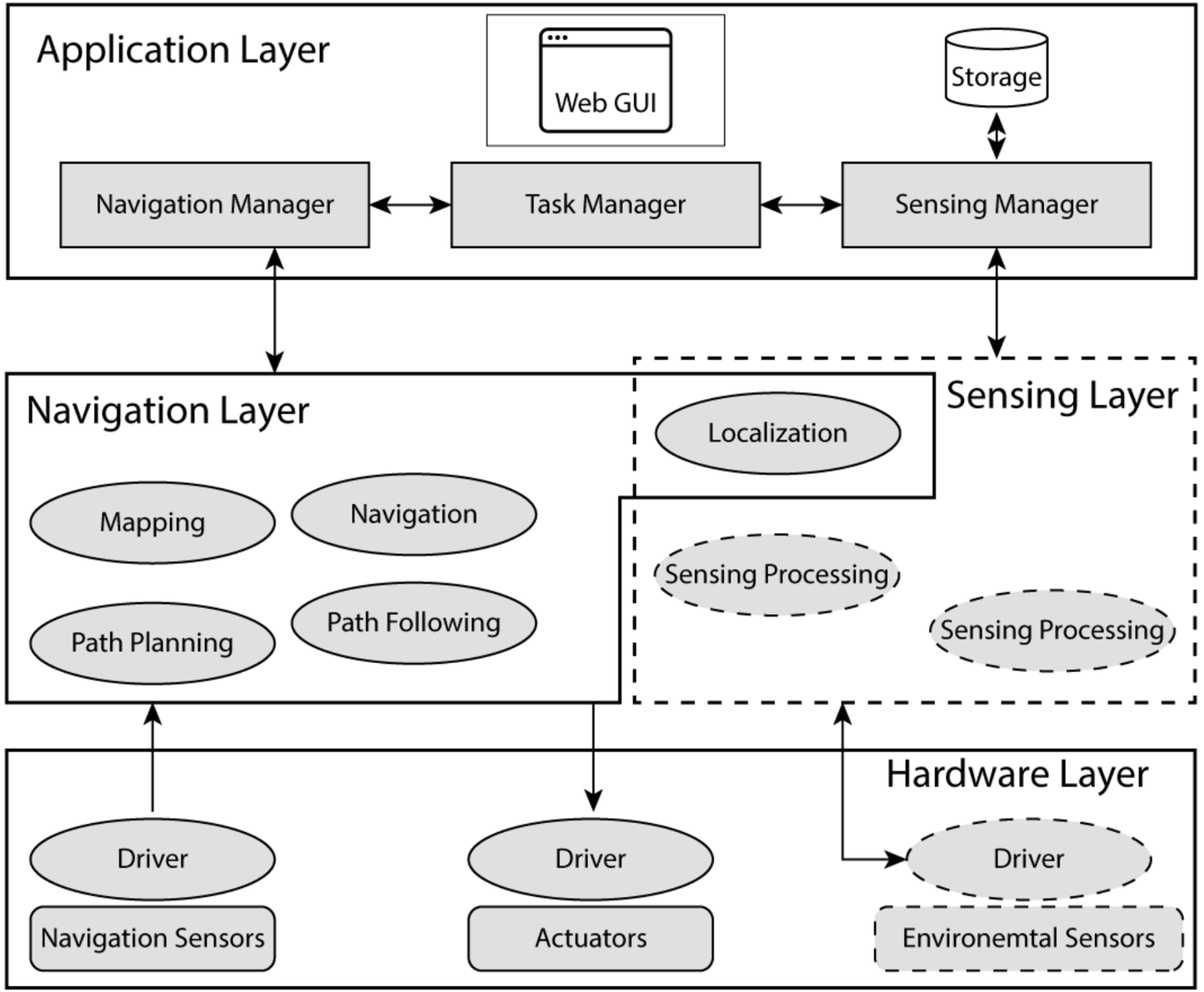
- Transparent to the User
- Robot Tasks are localized sources of Measurements
- The User can Reconfigure the system from a Web Interface

Bicsi

Applications

- Thermal Monitoring in Data Centers
- WiFi coverage monitoring in huge Buildings

Architecture



Thermal Monitoring in Data Centers

Data Center

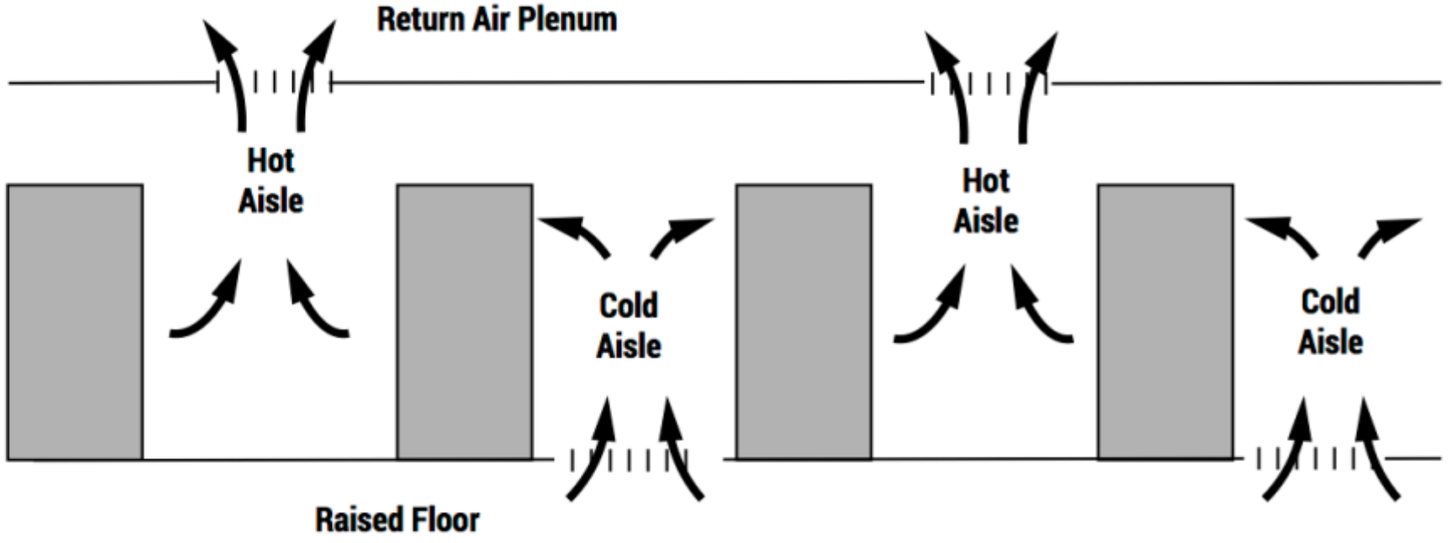
- Data Center are the most energy consumption building in the world
  - 1.5% of total electrical energy demand
- Energy Management of datacenter is expensive
  - Power the Servers
  - Cooling System
- PUE: Power Usage Effectiveness
  - 1.7 avarage

$$PUE = \frac{P_{tot}}{P_{IT}}$$

Bicsi

Free Air Cooling System

- The hot/cold Aisles layout maximizes the air cooling capacity
- Cold Air temperature and humidity must be controlled
  - **Optimal Ranges [20-24]˚ C - [40-55]%**



Data Center Monitoring

- All the solutions aimed at monitor temperature and humidity values in datacenter in order to:
  - Maintain the air values in the suggested optimal ranges
  - Detect HotSpots

Optimal Approach

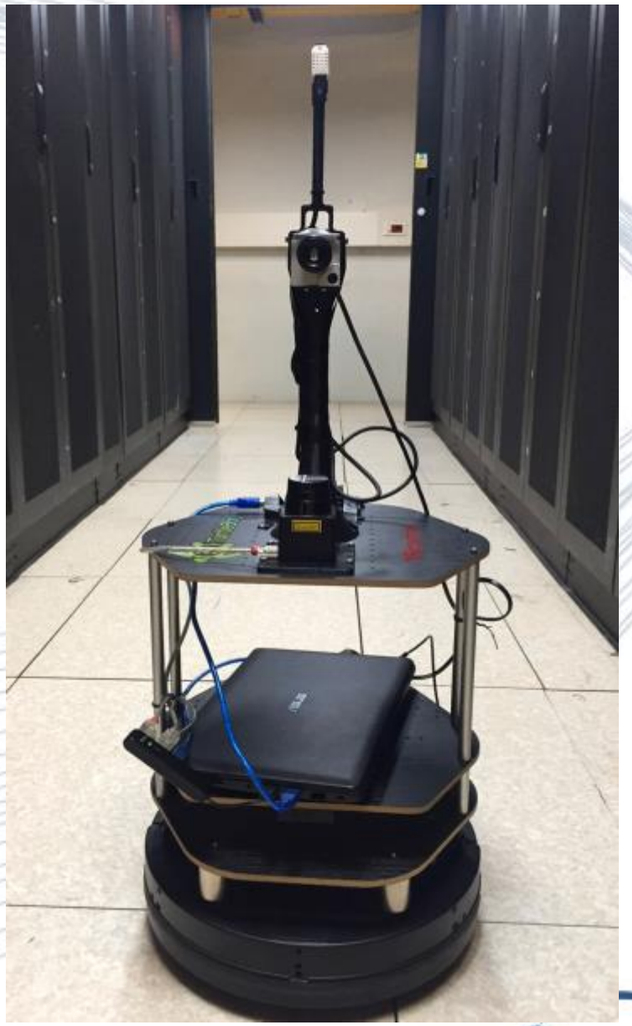
- Dense Sensing Network
  - Measurements Nodes (sensors) placed in each rack
- PROs:
  - RT measurements
- CONs:
  - Not scalable
  - High installation and maintenance costs
  - Difficult to manage

Practical Approach

- Sparse Sensor Network
  - Few Nodes each Room
- Human Operator that periodically inspect the Room

VSN Approach

- **Hardware Layer**
  - An Experimental Robot base platform
  - Temperature/Humidity Sensor
  - Thermal Camera
  - Laser Range Finder
  - Laptop running ROS
- **Sensing Layer**
  - Localized Temperature/Humidity logger
  - Localized Thermal Images logger
  - HotSpot Autodetection Algorithm

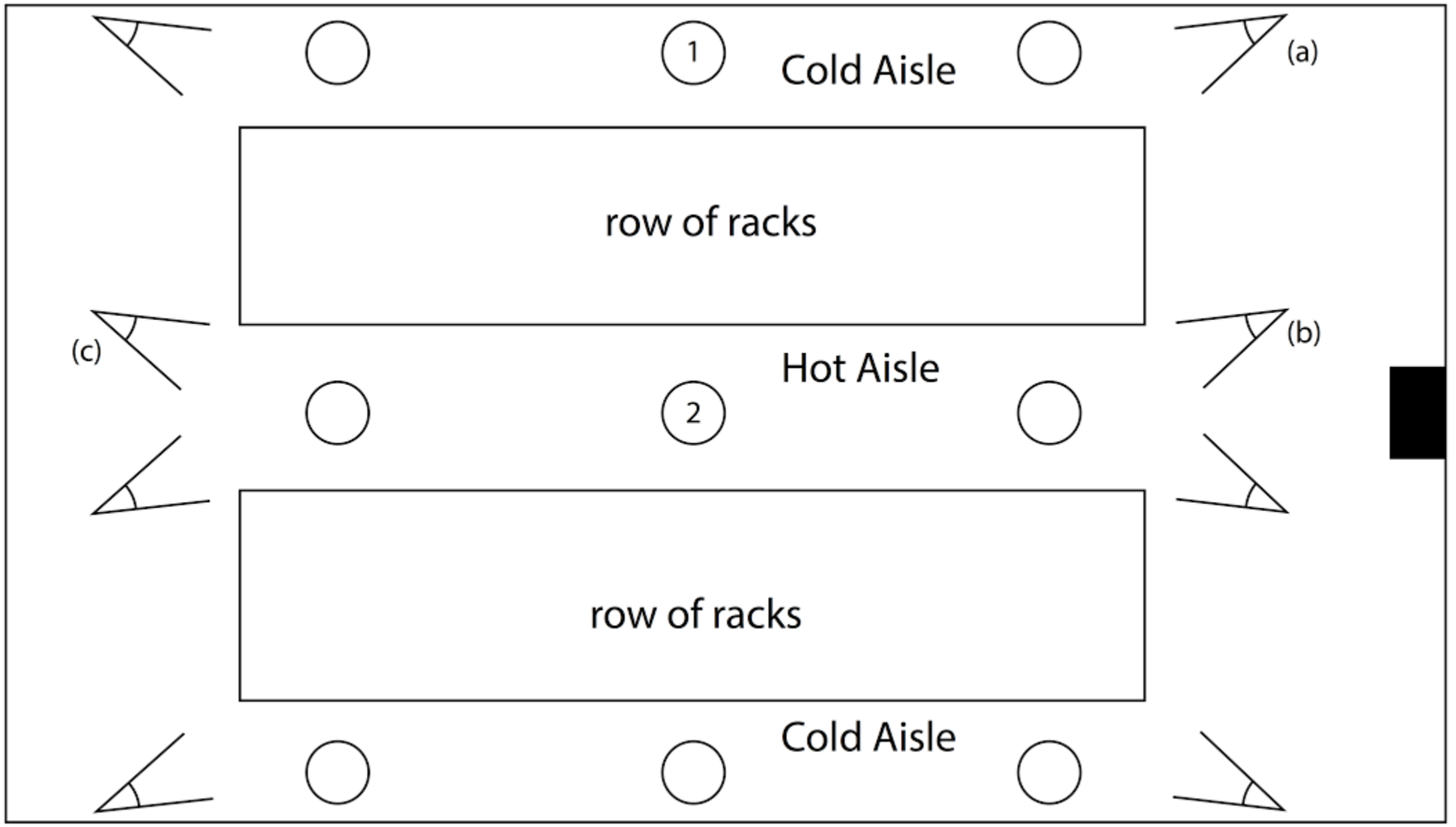


Bicsi

Data Collected in PoliTO DC

- Data Center of Politecnico di Torino
  - PUE = 1.53
  - 2 racks rows: 1 hot aisle and 2 cold aisles
- Security
  - Dedicated WiFi network
  - VPN to remote access
- Mapping in 5min
- 10 minute of recharging after each mission

Mission Setup

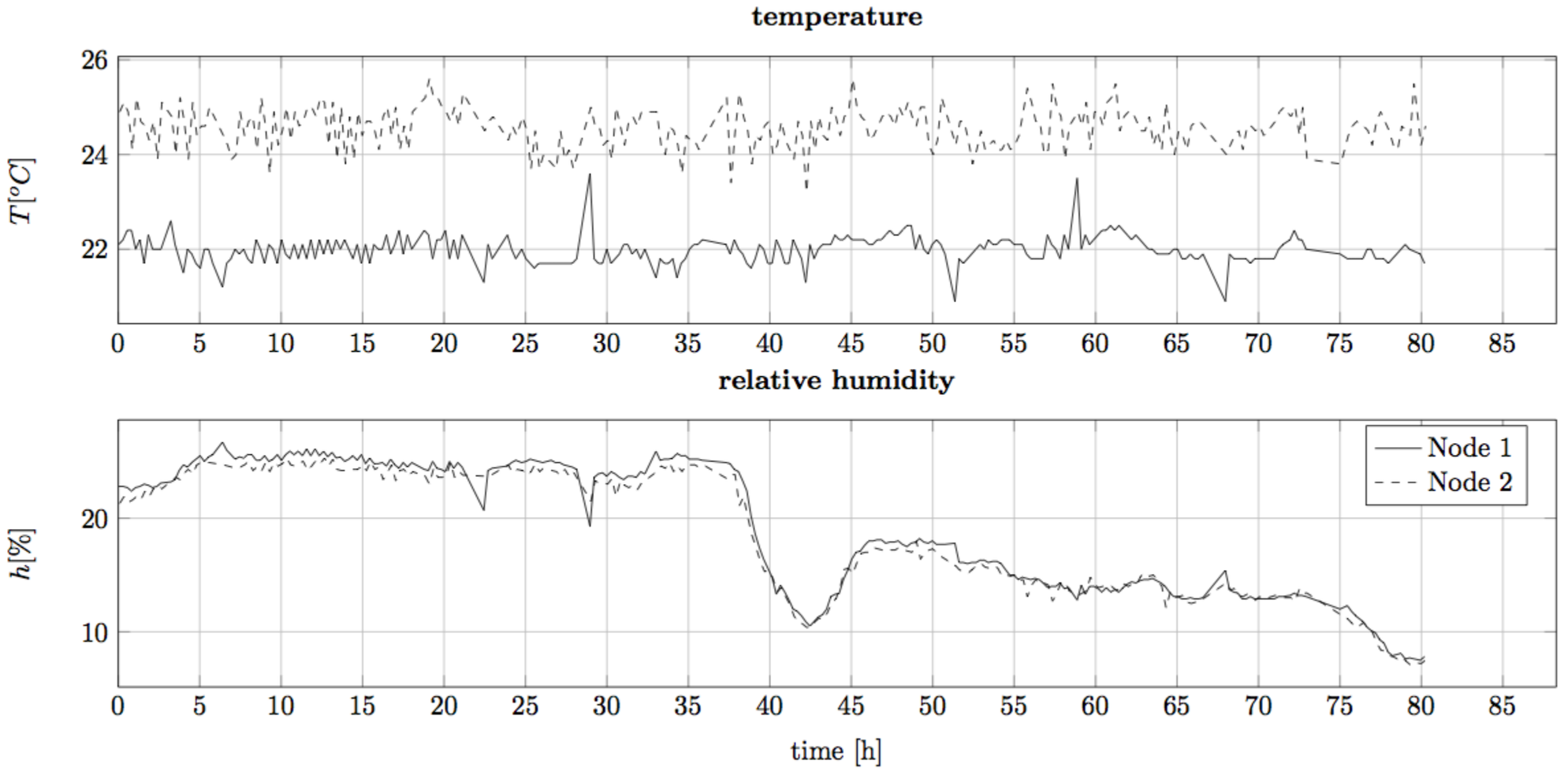


Temperature/Humidity node

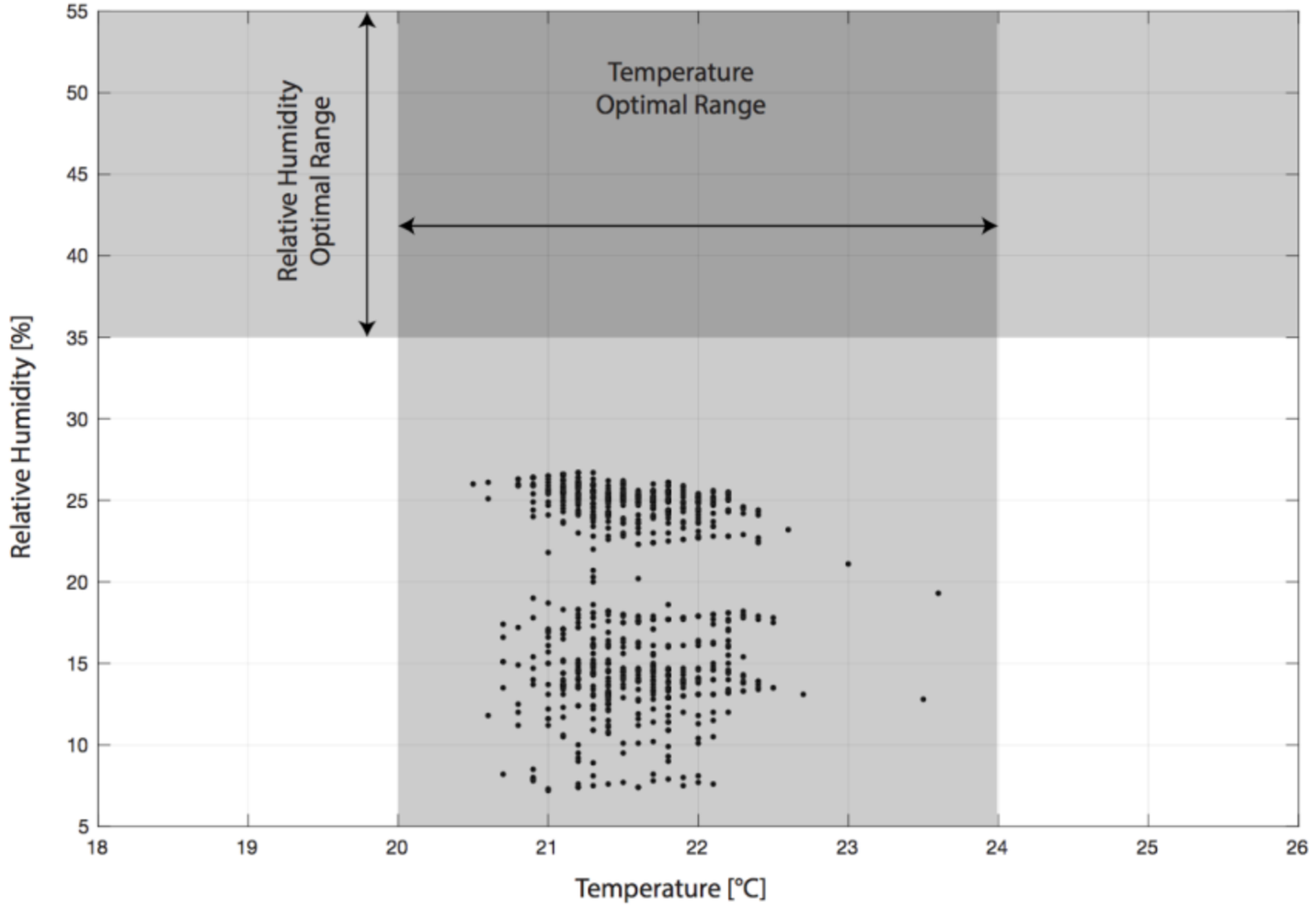
Thermographic node

Docking Station

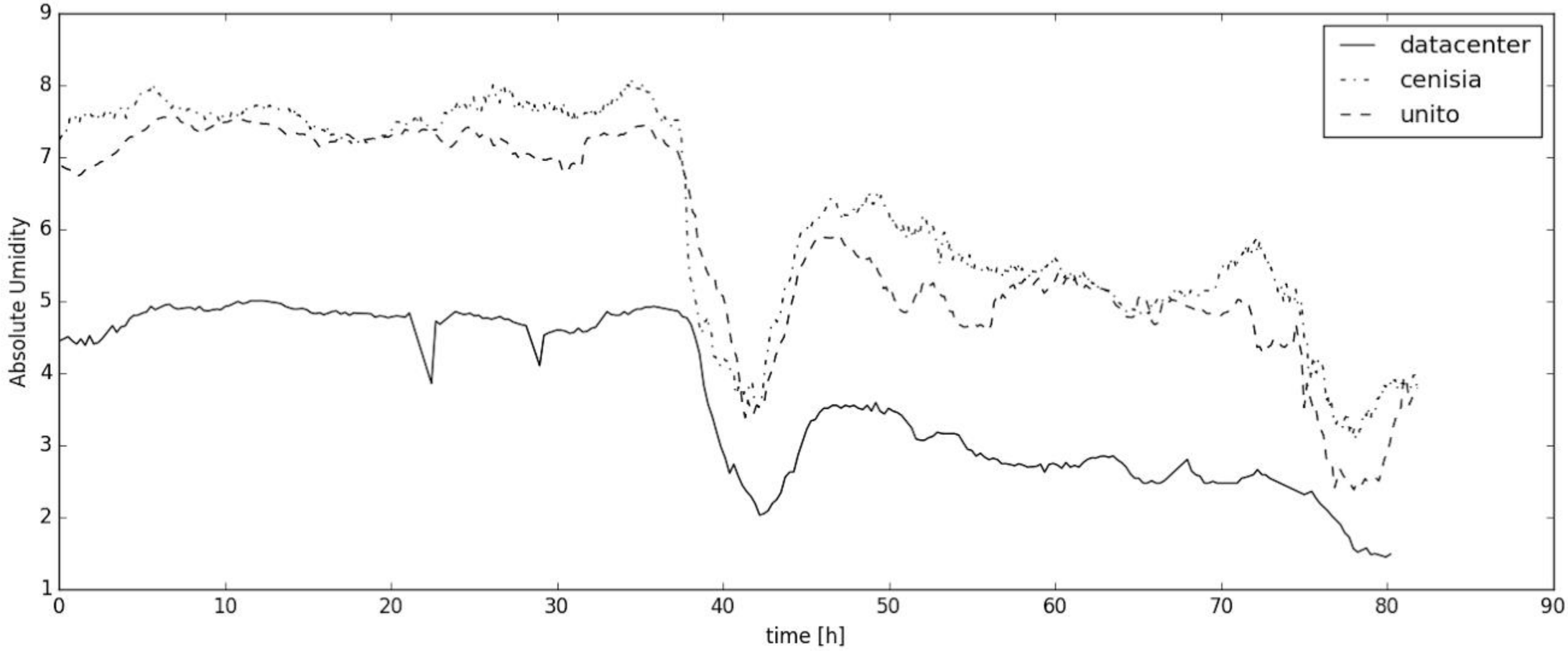
Humidity/Temperature Data (1)



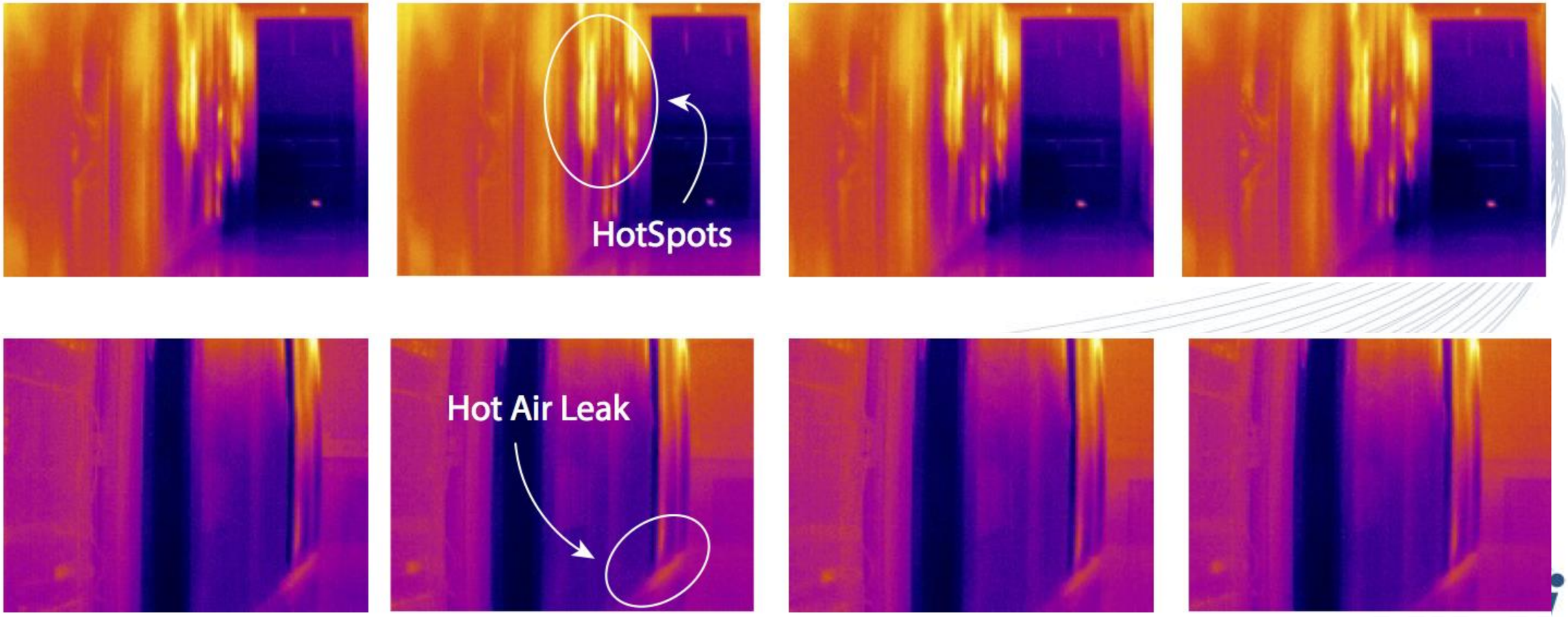
Humidity/Temperature Data (2)



Humidity/Temperature Data (3)



Thermographic Analysis (1)

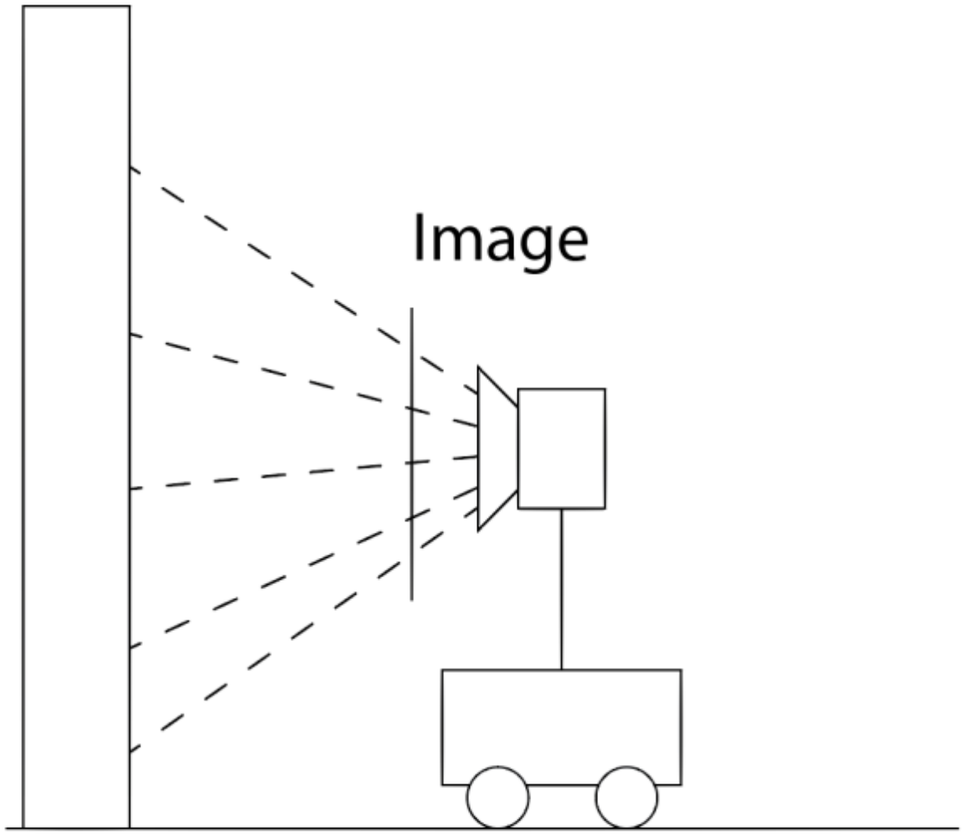


Thermographic Analysis (2)

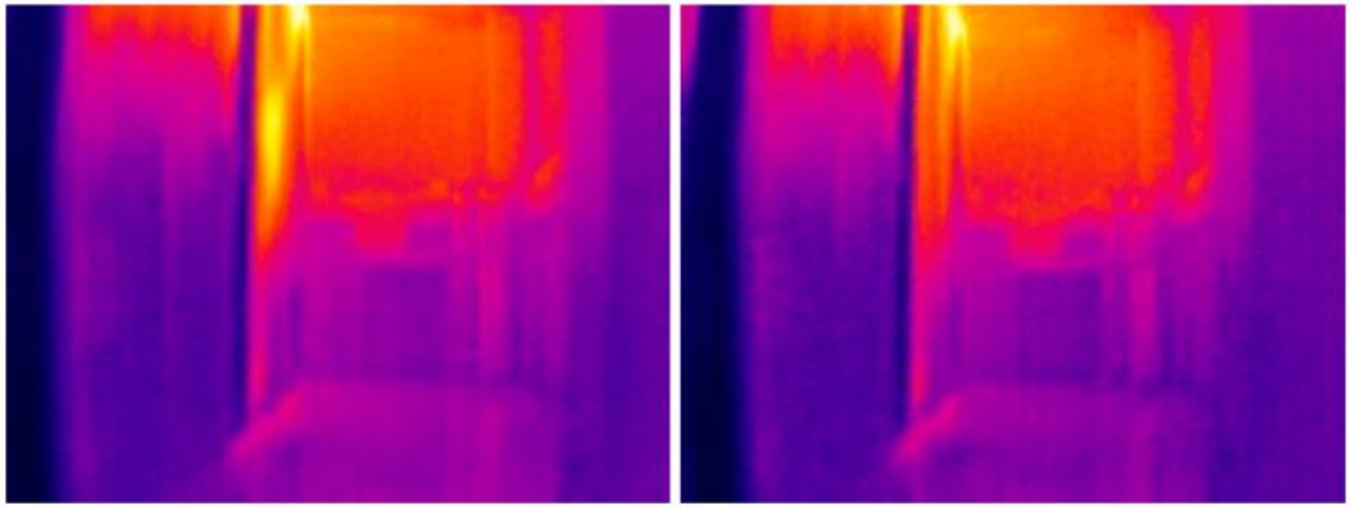
$$p_i^{(k)} = \begin{pmatrix} x_i \\ y_i \\ h_i^{(k)} \end{pmatrix}, h_i^{(k)} = \frac{k}{N+1} h_{max}, k = 1, \ldots, N.$$

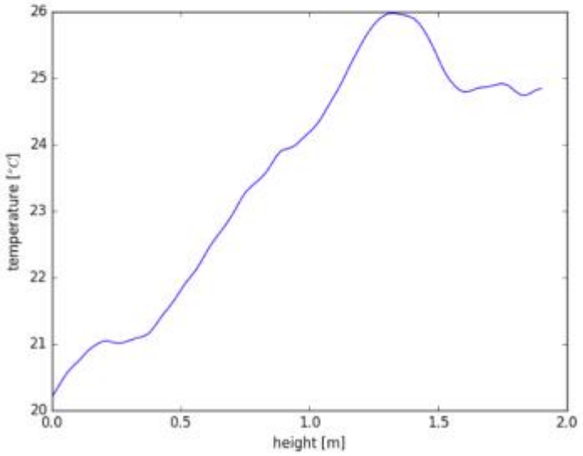
$$\tilde{p}_i^{(k)} = \lambda \begin{pmatrix} p_i^{(k)} \\ 1 \end{pmatrix} = KT \begin{pmatrix} p_i^{(k)} \\ 1 \end{pmatrix}$$

$$T_i^{(k)} = \mathcal{I}\left(p_i^{(k)}\right).$$

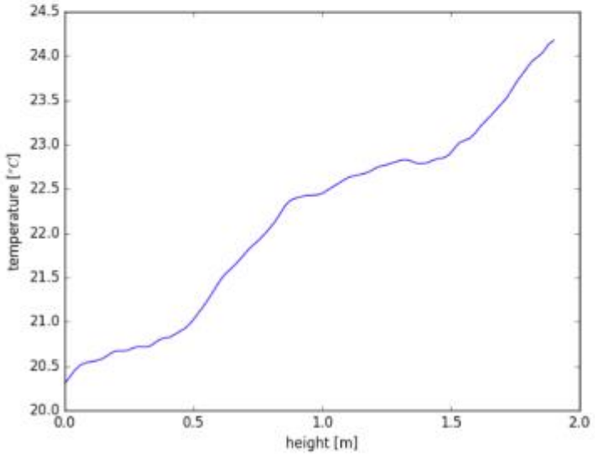


Thermographic Analysis (3)





(a) Rack without protection panel.



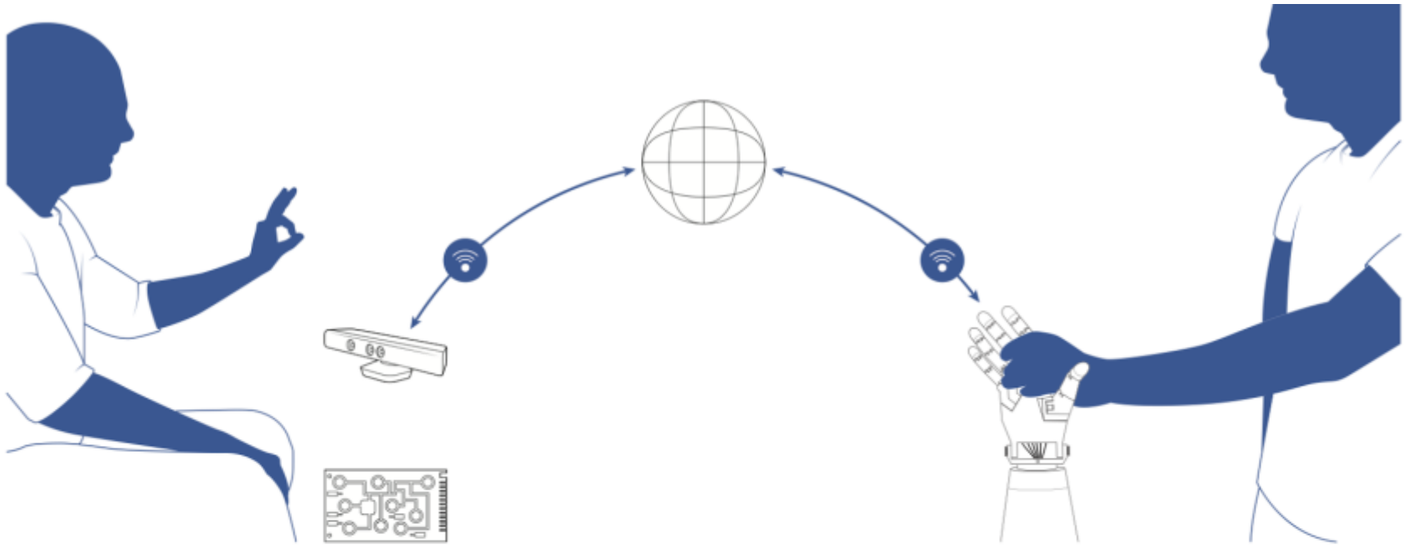
(b) Rack with protection panel.


Kobuki

Cloud Robotics – Other Applications

Bicsi

PARLOMA



The user signs in front of the depth-aware camera and the gestures are tracked and processed to produce skeleton poses.

The skeleton poses are acquired, encoded and transmitted via internet.

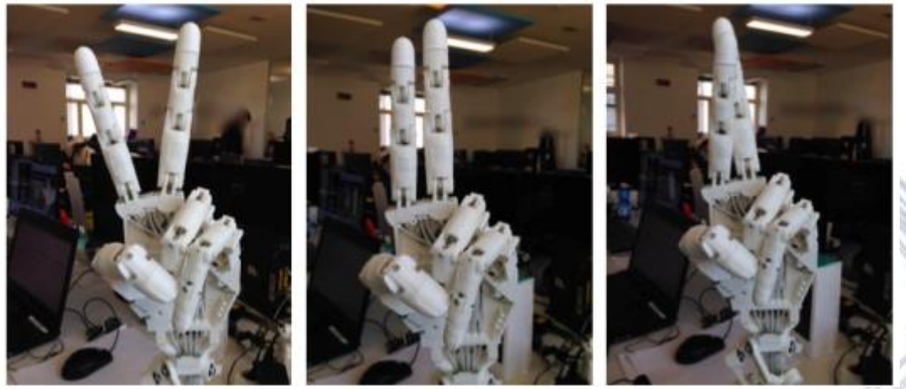
The skeleton poses are converted and sended to the motor control of the robotic hand.

Input Device

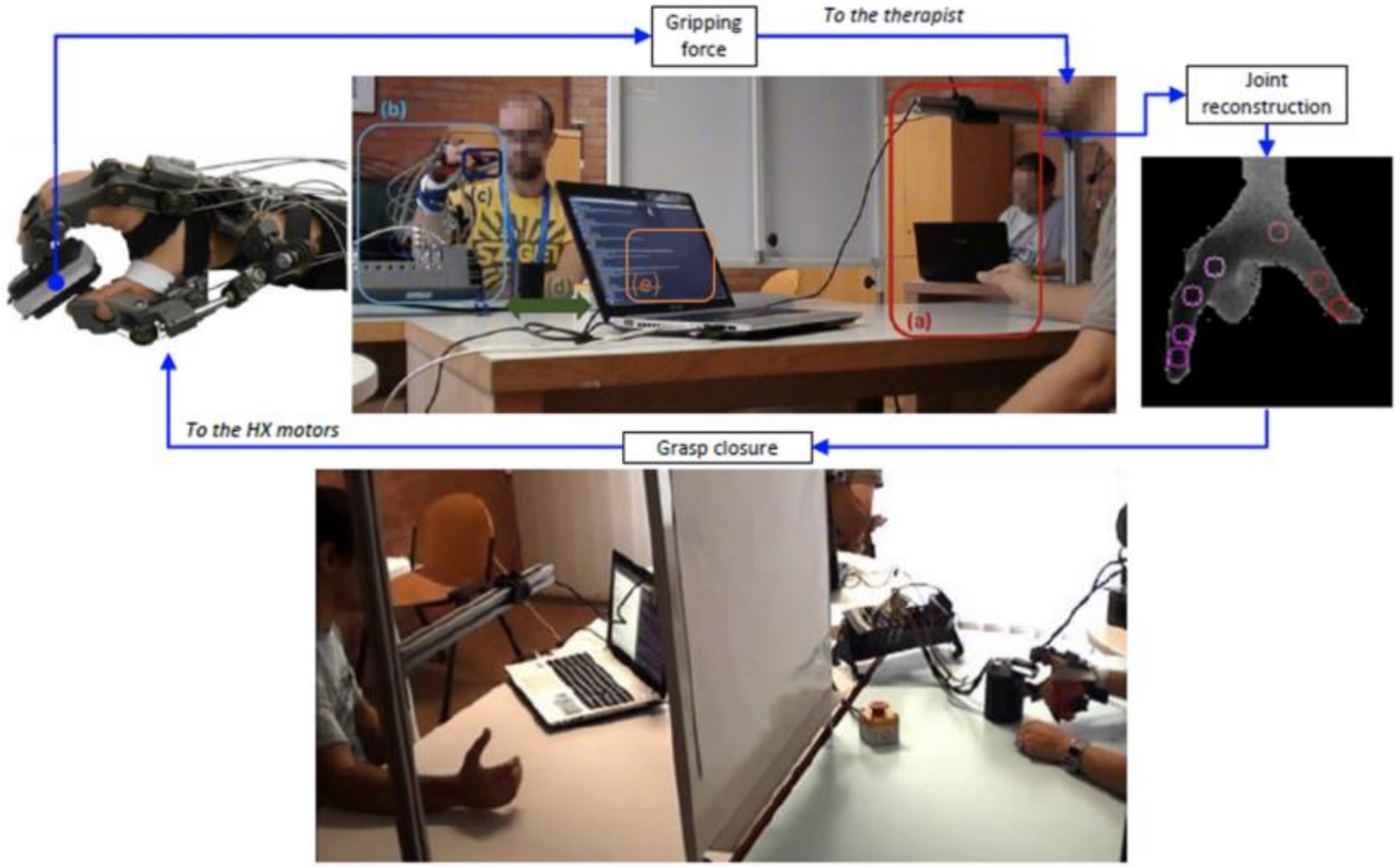
Cloud Robotic Platform

Reproduction

Robotic Hand printed Using the Open Source 3D printer Ultimaker



Tele-Rehabilitation



Thank You

Questions?